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(4) PICATINNY ARSENAL MONOGRAPH 34

(1) BONDING RARE METALS

BY

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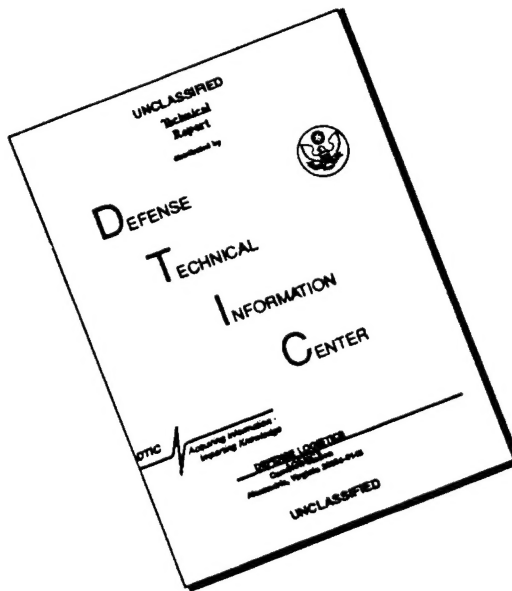
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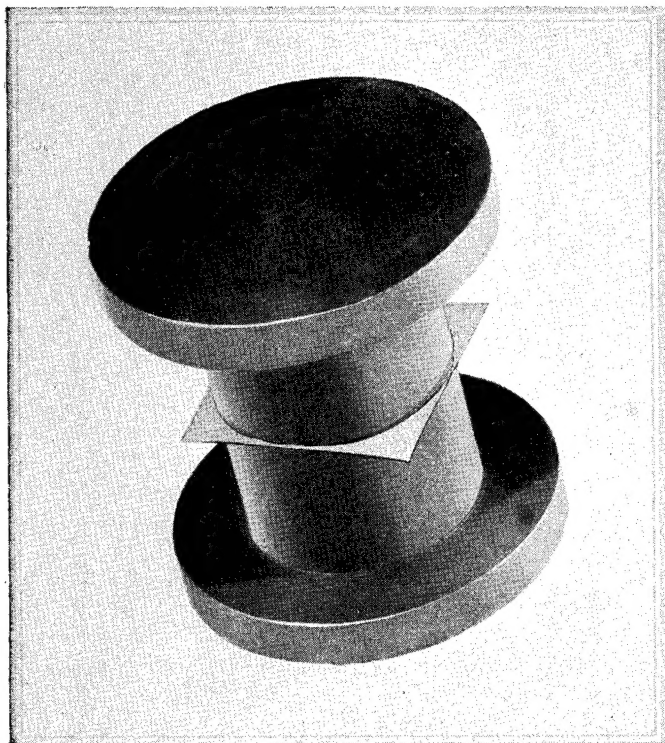


Fig. 1 — Tensile specimen for adhesion test method. Metallic foil is sandwiched between the tensile pieces.

What tests show  
about tensile strengths  
of adhesive bonds  
between uncommon metals

# Bonding Rare Metals

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**M**ANY rare and unusual metals have outstanding heat resistance and chemical stability. Where applications of these materials require smooth surfaces free from irregularities, adhesive bonding is generally specified. Results of adhesion tests with these metals are of special interest since bondability data are not readily available.

Steel specimens were bonded to beryllium, columbium (niobium), copper-beryllium alloy, molybdenum, palladium, rhenium, stainless steel, tantalum, tungsten, uranium, zirconium, and 720 alloy (manganese-copper-nickel). Also, chromium, gold, silver, stainless steel, and titanium were bonded to themselves. Tensile strength of the bonds is shown in Table 1.

Degree of adhesion obtainable also indicates the success that can be expected when polymeric materials are used as sealants or encapsulating compounds with these metals. Penetration of moisture through a sealed area depends not only on the moisture resistance of the sealant and adherend but also on the extent to which the moisture can penetrate the interface area between the sealant and adherend. Generally, if a low degree of adhesion is

experienced between two surfaces, moisture may conceivably penetrate the sealed joint through microscopic voids.

**Metal Preparation:** No special cleaning procedure was used to prepare the metal surfaces. The specimens, with certain exceptions, were vapor degreased with perchloroethylene before applying the adhesive. The exceptions were beryllium, uranium, stainless steel (for bonding to itself), and titanium. Beryllium and uranium form oxides which were removed by special abrading processes developed at Picatinny Arsenal. Stainless steel and titanium were treated by cleaning with a dilute chromic-acid solution.

**Adhesives:** Two types of adhesives, a rigid polyester and a filled novolac epoxy, were used to bond all specimens except the uranium-steel combination, Table 1. Because of the special problem involved in bonding to uranium, two other adhesives were selected as a result of successful adhesion achieved in long-term storage tests. These were an epoxy modified with a polyamide and a polyurethane.

**Test Specimens:** In all cases where the rare metals

Table 1—Adhesive-Bond Strength at 73.5 F

Bonded Materials	Adhesive*	Tensile Strength (psi)
Steel to:		
Beryllium	A	4820
	B	4640
Columbium	A	5010
	B	3400
Copper-beryllium	A	6240
	B	3940
Molybdenum	A	4840
	B	4575
Palladium	A	5200
	B	4315
Rhenium	A	6410
	B	3235
Tantalum	A	4100
	B	3300
Tungsten	A	5470
	B	5025
Uranium 238	C	1184
	D	1300
Zirconium	A	5490
	B	3590
720 Alloy	A	3600
	B	3135
Metals to themselves:		
Chromium	A	7160
	B	5010
Gold	A	8610
	B	3950
Silver	A	3780
	B	5625
Stainless Steel 347	A	8500
	B	6070
Titanium	A	9920
	B	5665

*Adhesive	Name	Description	Supplier
A	Epiphen 825A	Modified, filled, epoxylated novolac	The Borden Chemical Co.
B	Laminac 4116	Rigid, modified polyester	American Cyanamid Co.
C	Epon 828/Versamid 115	Bisphenol A-epichlorhydrin epoxy modified with a polyamide	Epon, Shell Chemical Corp.; Versamid, General Mills Inc.
D	Adiprene L	4, 4' Methylene bis (2-chloroaniline) cured polyethane	E. I. du Pont de Nemours & Co. Inc.

were bonded to steel, specimens were prepared by sandwiching the metal between two steel tensile pieces as described in ASTM test methods, Fig. 1. The gold, silver, and chromium were plated onto the bonding surfaces of standard tensile pieces. Except for the beryllium and uranium, the bonded area for each test specimen was 1 sq in. The beryllium had a surface bonding area of 0.785 sq in. and the uranium had a surface bonding area of 0.56 sq in. All specimens were cured at room temperature. Tests were conducted at a constant rate of load increase applied at 600 to 700 psi per min in accordance with Federal Test Method Standard No. 175.

**Bonds Obtainable:** Good bonds were obtained with the polyester and novolac epoxy adhesives. For the uranium-steel combination, bond strengths were approximately the same for the epoxy/polyamide and the polyurethane adhesives. The novolac epoxy, adhesive A, Table 1, provides higher bond strength than the rigid polyester, adhesive B, to all metals except silver. The lower results obtained with silver, however, are to be expected since the novolac epoxy adhesive is modified with a polysulfide polymer which readily attacks metallic silver.

Although data shown are for specific metal-to-metal bonded joints, approximate bond strengths obtainable can be calculated for any combination of the metals reported here. For example, if columbium were bonded to gold, the results would be expected to be no better than the adhesion to columbium. At room temperature, the bond strength obtained will always be equal to the bond strength obtainable to the metal with the lowest surface adhesion properties. At other temperatures, differences in thermal coefficients of expansion may have to be considered.

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## They Say . . .

"Mathematics is the central directive agent of the whole human quest for quantitative understanding of the environment. It is in command at all points in man's efforts to apply nature to his advantage. It is the medium through which chaos and superstition are banished. It is the backbone not of one science or of several, but of all science . . ."—RUDOLPH E. LANGER, *director U. S. Army Mathematics Research Center, Univ. of Wisconsin.*

"Our political, our economic, and our social systems flourish when we discipline ourselves not only to accept responsibilities but to strive for the highest excellence in our personal achievements, and when we recognize by public acclaim and position those who achieve that excellence. Engineers have no greater right to acclaim than others of our citizenry. By the very nature of their training and their work, however, they have developed mental discipline which entails a responsibility to put that discipline to work."—JOSEPH W. BARKER, *chairman of the board, Research Corp., New York, N. Y.*